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Indigenous Practices for Achieving Sustainable Construction

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Abstract

The objective of the present research is to explore the concept of sustainability in construction by examining indigenous construction practices followed in various regions of India, in line with the Sustainable Development Goals (SDGs) that promote safe, resilient, and environmentally friendly human settlements. This study aims to investigate indigenous construction practices that have been used for generations and assess their applicability in the present context. Through the collection of qualitative data from participants, the study seeks to develop a theoretical model of sustainable construction that incorporates region-specific indigenous practices. As Constructivist Grounded Theory (CGT) lends itself useful for such theory development, we have used it as the methodology for data collection, analysis and model development. CGT enables in-depth inductive analysis of qualitative data. Data have been gathered through interviews and conversations as primary sources, supplemented by secondary sources. The study primarily focuses on key parameters such as construction materials and techniques, labour, economic considerations, and region-specific indigenous practices related to sustainable construction. This study develops a theoretical model that integrates indigenous practices with contemporary practices, and thus endeavours to bridge the past and present, offering a blend of traditional wisdom and contemporary relevance. It aims to inspire customers, architects, and engineers to reconnect with their cultural heritage and embrace local knowledge in construction practices, which have demonstrated sustainability over thousands of years. Findings from the study pave the way for better environmental management through sustainable indigenous construction practices.

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Introduction

As urbanization continues to encroach upon natural habitats and rural areas, there is an urgent need to comprehend the sustainability concept within modern construction industry. The global imperative to safeguard the environment for future generations has led to the recognition that embracing sustainable construction practices is crucial. Aligned

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with this objective, the Sustainable Development Goal number 11(SDG 11) about sustainable cities and communities calls for action to "make cities and human settlements inclusive, safe, resilient and sustainable". Responding to this goal, the present study focuses on shedding light on the concept of sustainability by exploring the utilization of indigenous construction practices in India. The inclusivity aspect of SDG 11 is covered by proposing to include indigenous construction practices in modern day buildings. By integrating the indigenous practices with contemporary practices, safe and resilient construction is possible; which would be sustainable and hence protect the planet.

The primary aim of this study is to examine indigenous construction practices and assess their relevance in the present context. India, with its diverse cultural landscape and various housing and settlement patterns, necessitates an understanding of different value systems, perceptions, and ways of life. The study recognizes the importance of capturing the perspectives and interests of individuals in relation to sustainability in indigenous construction practices.

Key parameters identified for this study encompass

i. Construction materials and techniques- This includes indigenous construction materials and techniques which have the potential to be used in present times.
ii. Labour considerations- The use of indigenous construction materials and techniques involves employment of trained labour in this craft, which is a significant challenge in many parts of the country, especially in urban areas.
iii. Economic aspect of sustainable construction- Cost of using sustainable construction practices, especially the indigenous ones, may be different from contemporary methods, and is an important area for research.
iv. Region-specific indigenous practices- Due to the vast variety of geographical conditions in India, there are region-specific construction practices which demand detailed research.

By gathering qualitative data from participants, the study endeavours to develop a theoretical model of sustainable construction that incorporates region-specific indigenous practices.

In the present study use of indigenous practices in construction is researched with the aim of establishing a desired state of the world that is more sustainable. The main audience of this study is the common man who wants to understand sustainable construction practices. This study evaluates the value, practicality, and functionality of indigenous practices in the present times. Although the LEED and GRIHA ratings acknowledge the use of certain indigenous practices there is a greater need for a research which is completely focused on building a model which takes care of every aspect of indigenous practices in construction. Thus, the present study fills the gap of having normative and descriptive research that can support the development of theories. Ultimately the objective of the study is to "develop a theory that makes indigenous practices relevant in present times." As Constructivist Grounded Theory (CGT) lends itself useful for such theory development, we have used it as the methodology for data collection, analysis and the model development. To this extent, this paper also entails a methodologicalcal innovation in the use of CGT for construction management research with reference to indigenous practices, as it has hitherto been uncommon to use CGT in construction management research Details of CGT are mentioned in the research methodology section.

The paper is an attempt to bring back the past and make it relevant in contemporary times. Thus, having the best of both worlds. It inspires the customers as well as the architects and engineers to get in touch with their traditions, thus tapping into the local wisdom regarding construction practices, which has proven to be sustainable for thousands of years. This research provides a comprehensive model which can reshape future construction practices in India. There is an urgent need to integrate sustainable construction practices with mainstream construction practices and this paper highlights that we need to look back into our own history to accomplish this.

The paper is organised as follows. The introduction is followed by literature review covering relevant literature on the topic. This is followed by research methodology, covering the details of constructivist grounded theory, data collection and data analysis. After this, detailed findings and results are presented covering the key parameters of the study as

subsections. This is followed by the discussion section which presents the model developed in the study. The paper ends with conclusion and limitations and scope for future research.

Literature Review

The field of sustainable construction encompasses various complex dimensions within human settlements, as outlined by Hill and Bowen.[1] Four pillars of sustainable construction as identified by them included: social, economic, technical, and biophysical and they advocated the use of a checklist for practical implementation. They also suggested a framework for construction projects consisting of environmental assessment.

Highest level of criticism faced by the construction industry is the excessive consumption of natural resources during the construction and design phases, emphasizing that sustainability cannot solely rely on project design.[2] To address this issue, use of a sustainability index is recommended to measure a building's contribution to the environment. Robichaud and Anantatmula[3] emphasized the economic aspects of green buildings and discussed the potential for retrofitting conventional buildings. They also made suggestions regarding project management practices that can enhance the financial viability of green projects.

While sustainability is increasingly important for the construction industry, it becomes crucial to broaden perspectives beyond economic and short-term considerations.[4] A different approach to designing construction activities for sustainability is necessary, and indigenous practices offer a way forward by considering the environment, economics, and social aspects of construction.

Efforts have been made to uncover age-old indigenous practices and apply them in contemporary construction to achieve Sustainable Development Goals (SDGs). The evolution of building materials, from thatch and mud to bricks, steel, and cement has accompanied the evolution of housing from simple caves to elaborate bungalows. Studies demonstrate that construction activities significantly contribute to environmental pollution through the use of conventional materials.[5,6] Utilizing sustainable materials can help mitigate impact of construction activities on the environment. Therefore, it is necessary to study vernacular architecture, which emphasizes local context, culture, tradition, and harmony with the environment through the use of local materials, design styles, and consideration of the local climatic conditions. A comparative study between old and new buildings by considering the parameters such as materials, vegetation, interiors, and sociocultural values was done.[7] The authors discussed the differences between contemporary and vernacular architecture by identifying ideological gaps in contemporary building structures. Indigenous materials as potential alternatives to modern building materials has been examined and the incorporation of vernacular architecture concepts in environmentally positive building design has been reviewed.[8] The collaborative design process involving indigenous communities, highlights four main design principles: culture, lifestyle, traditions, and values.[9]

The use of local materials for construction activities yields economic along with sustainability benefits through a reduction in carbon emissions.[10] have stated climatic conditions, local geography and geology, socio-economic status of the owners and local skills as the influential factors for indigenous structures. [11] emphasized that traditional environmental and cultural preferences have a great impact on the house design.[12]

Local construction solutions have evolved from local resources, methods, wisdom and cultural choices of the area.[13] The labour required for the construction of traditional buildings is sourced locally and they are either from household or from local community.[14] Thus, there is saving on labour related costs.

Use of local material and indigenous technology is an integral part of housing construction in rural India.[15] Research on housing patterns in India revealed that housing is the mirror of culture of the people and it is the integral part of the social life of the people living in them.[16] Traditional houses are made up of natural materials like bamboo, cane, mud, and wood which is available locally and cost of construction of these houses is minimal.[17] Houses in rural areas are built using mud. The enhanced durability of the walls yields maintenance cost of these houses low.[18] Also, cost of maintenance of traditional houses is less compared to the modern houses.[17]

Wider acceptability of houses constructed using traditional materials can be traced with their contribution to the local economy.[14] The role of sustainable construction in India is emphasized in literature.[19] Based on the housing pattern studies, use of natural materials and agricultural waste promotes sustainability of the traditional houses.[20] The houses constructed using traditional materials exhibit variety as each house is built according to the choice of individuals. Thus, such houses create a better, cultural and psychological environment. Traditional building materials are derived from earth and hence are cost effective. This ensures economic sustainability of the structures built using these materials.[20] Table 1 provides a brief of various types of indigenous construction practices, with their direct application in enhancing the quality of the building.

Table 1: Indigenous construction practices with areas of application

No.	Indigenous practice (IP)	IP definition	Applications	Visual Impact
1	Jharokhas[21]	Jharokhas are extensions placed on building fronts/ corners.	Improve visibility, air-conditioning	Light Shadow play, cultural Symbolism, architectural beauty
2	Courtyard[22]	These are the enclosed outdoor spaces that are normally open at the top	Social gatherings	Natural light and ventilation, social significance
3	Jaalies[23]	Jaalies are the lattice screens employed in ancient Indian architecture for ventilation	Ventilation	Cooling effect, cultural impact
4	Verandah[24]	Verandah is an open space in front of the house.	Social gatherings	Connection with nature, social space, climate
5	Chhajjas[25]	Chhajjas is a modular system of arches that are filled with delicate latticed screens to cut the effect of direct sun rays.	Cooling effect, improving air quality	adaptation Asthetics, climate adaptation, cultural significance
6	Koti Banal[26]	House structure found in Uttarakhand State of India	Earthquake resistant houses	Asthettics,intergation with nature, structural
7	Bhonga[27]	Circular house structure found in Rajasthan State of India	Min. exposure to hot and dry climate	stability Integration with nature, culture
8	Naalukettu[28]	Traditional vernacular houses in Kerala State of India	Protection from heavy rainfall	Traditional woodwork, craftsmanship
9	Wattle and daub houses[29]	Traditional houses built in central India by using bam -boo in the middle followed by daubing the mud	Low-cost housing using traditional materials	Organic colours, asthetics, environmental adaptabiity
10	Ikra houses[30]	Single-story houses built using bamboo and wood in Assam State of India	Lightweight and earthquake resistant houses.	Cultural adaptation, organic shape, integration with landscape

The above secondary data-based analysis has significantly contributed for building theory for indigenous construction practices.

Thus, it can be observed from the literature review that various studies highlight the value of indigenous construction practices, and they have

even been acknowledged while giving green building certifications, but there is no framework exclusively for the use of indigenous practices in construction. This research gap is fulfilled by the present study by providing a model for sustainable construction using indigenous practices.The model presented in this study is a comprehensive solution for the end-user, covering all the key parameters for integrating indigenous construction practices with contemporary construction practices.

Research Methodology

The field of construction management is currently at a turning point where researchers are creating distinct but complementary research streams, separate from those in architecture and engineering. Due to the practical application of research in construction, normative research has become the research focus.[31] Normative research entails determining how research findings should be applied to the study population, while also establishing the context, defining phenomena, and interpreting results. This type of research involves measuring, evaluating, and comparing the value, practicality, and functionality of a given subject. In general, normative research is concerned with evaluating and making value judgments, as well as providing instructions on how to achieve the desired state of the world. Sound justifications or reasons are typically provided in normative research to justify a particular outcome. Thus, the present study fills the gap of having normative research that can support the development of theories. Ultimately the objective of the study is to "develop a theory that makes indigenous practices relevant in present times." As Constructivist Grounded Theory (CGT) lends itself useful for such theory development, we have used it as the methodology for data collection, analysis and the model development.

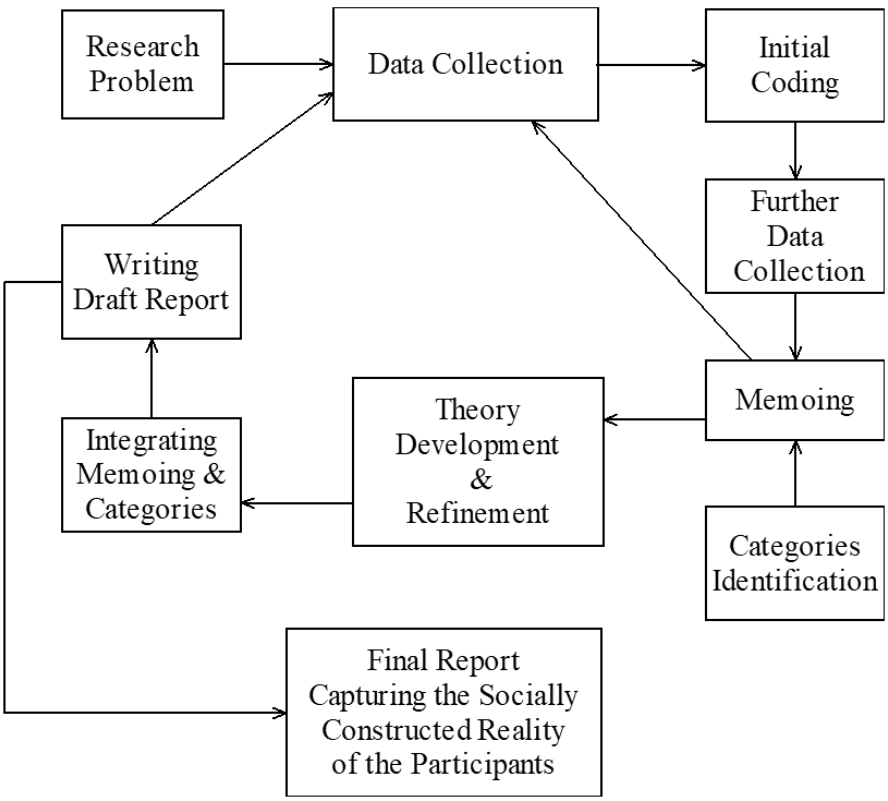

Fig. 1: Constructivist grounded theory

(Source: Image modified from35)

Rooted in interpretivist philosophy, the present study has a normative approach that utilizes the principles of CGT. As the term 'normative' implies, it establishes standards for behaviour by explicitly defining feasible, desired, or possible ways of acting. Additionally, normative research sets expectations for social interactions. In the context of sociotechnical research, normative research focuses on making desirable ways of behaving visible, while also describing the causal relationships between actions. The present study accomplishes this normative aspect of studying sustainability through indigenous construction practices by identifying the feasible and desirable ways of acting through collecting useful data from industry experts. As CGT is an empirical form of inquiry grounded in experiences, it is a suitable method for present study.[32,33] The process of CGT involves transforming the way the researcher and participants interact during research, while also emphasizing the researcher's role as the author.[34] The CGT method is an inductive approach that finally describes the socially constructed nature of reality. By adopting a constructivist perspective that explores how reality is constructed, CGT diverges from the positivist approach of the Glaserian and Straussian Grounded Theory schools.[35] CGT also enables correspondence between chosen research methodology and the own world views of the researchers. The authors of this paper attest the world view of integrating the past with the present and getting the best of both the worlds, while not eulogizing or negating either the past or the present. This world view was reflected in the way interactions happened with the respondents. In CGT,[36] the research process consists of data collection, and develop analytic narratives throughout the inquiry. The diagrammatic explanation of CGT is given in figure 1. Such an inductive methodology is apt for the present study because the process of doing research for this paper also involves co-construction of the data with the respondents and the interviewers. The interviewers were aware of the locally and historically rooted context and were engaging in a conversation with the respondents rather than having a strictly question-answer session. The nature of the topic also demanded that open conversations happen so that meaningful practical insights may be sought.

Research Question

Using the above methodology, the present study addresses the research question: What can be a theoretical model of construction which optimally utilises all the aspects of indigenous construction practices in India?

Objective of the Study

The objective of this study is, to develop a theoretical "Model for Indigenous Construction Practices' which makes indigenous practices relevant in present times as well as easy to understand and implement even by non-technical audience.

Details of CGT employed in this study are given in the following steps.

Data Collection

The research process involved various steps, including data collection and the development and writing of analytic narratives. After conducting a literature review, the identification of the potential subjects for the study was done. The snowball or referral sampling technique was utilized, in which each potential subject tried to provide multiple referrals.

Data collection encompassed both primary and secondary sources. Informal interviews and conversations were chosen as the prominent data collection method. The identified potential subjects were architects who were actively involved in employing indigenous construction practices. Due to the COVID-19 pandemic during the data collection period (2020-21), most interviews were conducted through telephone calls. Interview questions were semi-structured and open-ended. The data documentation and analysis were conducted simultaneously, following the approach described by Kathy Charmaz.[37] Whenever the responses revealed new potential directions, the interview questions were restructured accordingly. The informal interviews continued until the researchers reached a point where no new directions emerged. A total of twenty architects, architecture enthusiasts, and practitioners, recognized for their notable contributions to construction as well as the environment, shared their insights for the study. The number of respondents was determined through snowball sampling, continuing until no new data could be collected, in accordance with Constructivist Grounded Theory (CGT) principles outlined by Kathy Charmaz.[32] CGT recommends data collection until the researcher no longer obtains new information

and stops when information begins to repeat. For a deeper understanding of the subjects, Figure 2 below presents a region-wise climatic classification map of India.

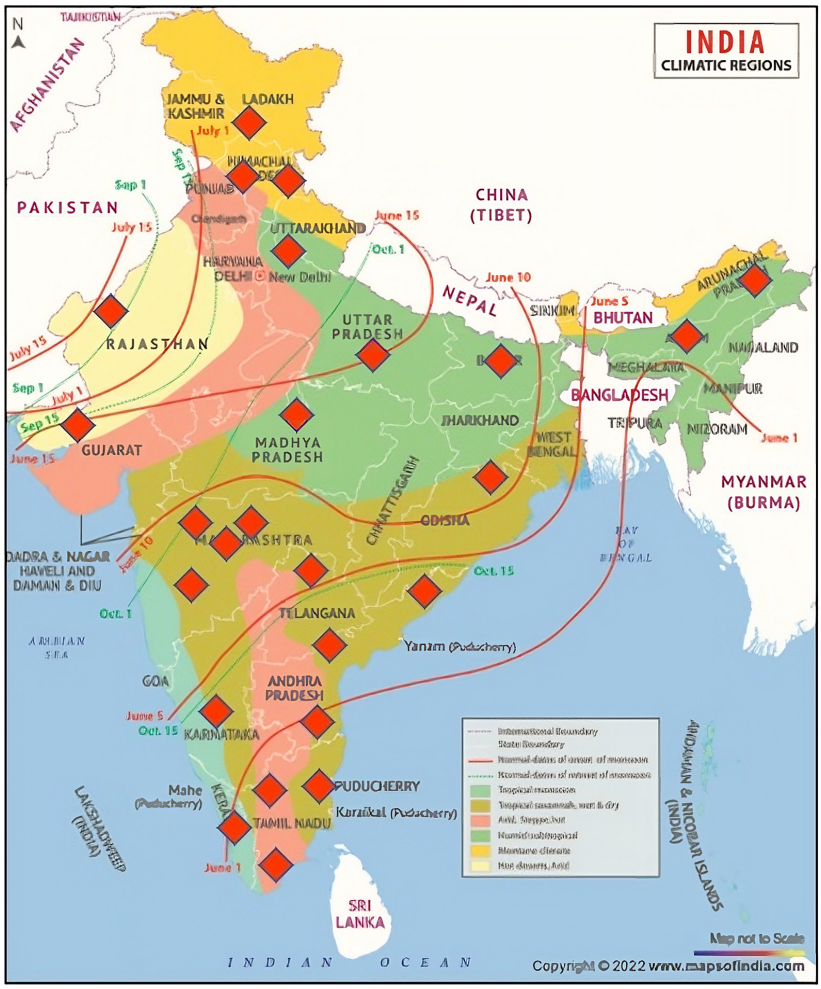

Fig. 2: Map of Potential Subjects of the Study[1]

Source: www.mapsofindia.com

The map provided above indicates the regions that were included in the study, represented by the colour red. The study drew insights from conversations with various prominent individuals, including Director, Centre for Indigenous Architecture, members of CEPT University students from Auroville Earth Institute, and practitioners. These interactions acted as the foundation for gathering valuable information on indigenous construction sustainability. Due to the aim of obtaining high-quality information, the study had a limited number of respondents. To ensure comprehensive data collection, interviews involved follow-ups or extended duration meetings, taking advantage of the principles of Constructivist Grounded Theory (CGT). It is to be noted that the selection of subjects was carefully made to include individuals from diverse climatic regions across the country. In order to maintain confidentiality and anonymity, the names of the respondents have not been disclosed.

Data Analysis

The data analysis commenced during the data collection phase to accommodate the dynamic

nature of the Constructivist Grounded Theory (CGT) methodology. All the data collected from the primary and the secondary sources were systematically examined and analysed. Additionally, the researchers employed observation as a suitable method for data collection. The data analysis process following the principles of CGT is outlined in Figure 3 below.

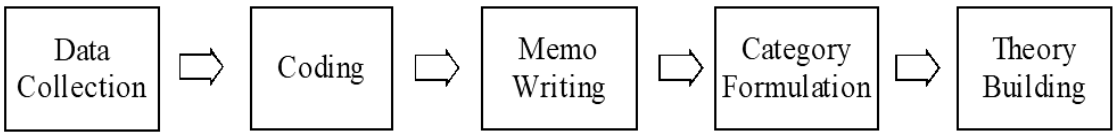

Fig. 3: Data Analysis Flowchart

Coding

As per CGT, after initial filtering, sorting, and cleaning of data and retaining the relevant statements, data was coded. These codes were in the form of long or short sentences. The coding was done along with data collection. Coding in this study revealed the main issues like use of natural materials, localization of construction practices, importance and impact on the local economy etc.

Table 2: Data Analysis

Statement by the respondent	Coding	Memo Writing	Category
"Most of these natural materials are commonly available in all the regions but the properties and quality of these materials depend on the geogra -phical terrain and climatic conditions."	There is a prevalence of use of locally available sustainable construction materials. of the geography of the region and should be chosen accordingly.	The locally available construction material need further understanding	Environmental Sustainability
"In earlier days, architecture had a broader humanities and social science focus."	Social issues faced by people should be the main concern while choosing construction practices.	Construction practices can ensure harmony between human and nature, leading to social development	Social Sustainability
"Eco-friendly buildings are not cheap; but these are economic in the long-run."	The economic viability of the construction practices is very impor -tant to the client.	Construction practices should lead to saving money in long-term pers -pective, which suggests that sustainability can be looked at in economic terms also.	Economic Sustainability

Memo Writing

Memo writing was done simultaneously with coding. It captures observations of the researchers as well as contextual details of the data collection process. This aided in a better interpretation of the data.

Category

The categories were identified at this stage for theory building. In this study, we identified three categories pertaining to sustainability through indigenous practices viz. environmental, social, and economic sustainability.

Theory Building
A meticulous comparison and interpretations of the codes, memo writing, and categories was done. This resulted in the formation of a model for sustainable construction through indigenous practices.

Sample Coding, Memo Writing and Categories
Table 2 below provides a sample coding, memo writing and category formation, which was done for all the qualitative data.

Reliability and Validity of the Study
Reliability and validity as used in quantitative research are not applicable in qualitative research due to its unique methods of data collection and analysis. In this research, reliability and validity of the study is established through the thick description, triangulations, analytical rigour and theoretical generalization.[38,39,40] In the present study, we have given a thick description by way of describing the context and interpretations of the authors. Triangulation has been achieved by corroborating the findings of the study with secondary sources of data as well as the incorporation of observations by the authors. Analytical rigour has been maintained by thorough data analysis as per the steps described in Figure 2. Theoretical generalization has been achieved by theorizing indigenous construction practices into a sustainability model as discussed in section 5.

Findings and Results
The findings are presented in four sub-sections pertaining to the four key parameters identified in the study.

Indigenous materials and methods of construction
One crucial milestone in the sustainability journey is enhancing resource efficiency. An architect respondent emphasized the significance of mud as the preferred material, particularly in rural areas. "*Mud is the de-facto construction material in the rural areas*". Mud has been utilized for construction by our ancestors for centuries, and many ancient mud structures still stand sturdy today. Its availability through on-site excavation results in a significantly lower carbon footprint compared to other construction materials. While mud may not be the sole alternative, it is currently the best choice considering the present context.

The principles of reduce, reuse, and recycle, known as the 3Rs, should guide modern building construction. Locally sourced materials naturally lend themselves to recycling. A practitioner based in Tamil Nadu provided the example of reusing doors/ windows from demolished buildings in his new projects, giving them an antique appearance while reducing construction costs. The ecological impact of wood as a building material varies depending on the type used. Teakwood, for instance, should be avoided due to the lengthy growth period of at least a decade. Instead, faster-growing timber options, such as neem, ain, and babul, which are abundantly available in Maharashtra, are highly encouraged for different construction applications.

Natural wood materials offer several benefits in construction, including sustainability, strength, durability, aesthetics, insulation, and carbon sequestration. However, they are not entirely renewable sources. Recent building designs have increasingly incorporated engineered wood as a replacement for natural wood, considering cost-benefit analysis and its lower environmental impact. Engineered wood, also known as composite wood, is a wood-based product created by binding wood fibres, strands, or veneers using adhesives or other methods. Although it offers advantages such as improved strength and dimensional stability, it also presents limitations in terms of life cycle assessment, including manufacturing impact, end-of-life impact, durability, and dependence on natural wood for production.[41]

The choice of materials in indigenous construction is influenced by geographical terrain and climatic conditions. "*Most of these natural materials are abundantly available in all the regions. However, the materials properties and quality depend on the geographical terrain/ climatic conditions.*", revealed an architect. Different regions exhibit variations in available timber, with coastal areas having tall timber growth and deciduous regions experiencing slower growth. Each type of wood possesses distinct properties. For example, babul excels in compression, while neem excels in tension. As a result, babul is used for columns and neem for beams in traditional construction.

Indigenous construction styles draw inspiration from ancient architectural practices tailored to specific geographical regions and designed to meet climatic requirements. According to some architects:

"A simple way for indigenous practices adoption is to observe changes and adopt them".

"Inspiration is derived from traditional vernacular architecture around the site. Best practices are implemented and others are changed as per requirements."

We can see that architects emphasized the importance of observing and adopting changes in indigenous practices while modifying the way materials are used. Good practices from traditional vernacular architecture are implemented, and adjustments are made as necessary. Thorough reconnaissance within a 20 to 30 kilometres radius around the construction site is conducted to understand locally available building materials and technologies. Indigenous construction prioritizes sustainability based on client requirements and site-specific climatic conditions. Innovative concepts rooted in traditional ecological knowledge, such as roof extensions in heavy rainfall areas, are incorporated.

"*There is no fixed indigenous construction style. The houses we design in each region are entirely different. We only introduce few elements depending on the availability and requirements.*"

The introduction of arches in architectural design offers several advantages. Firstly, arches possess a pure compressive structure, making them highly efficient. Secondly, they can be constructed using natural materials such as stone, providing both sustainability and versatility. In traditional structures, the walls tend to be approximately 450 mm thick. Consequently, this reduces the interior space within the house, resulting in lower furniture requirements and easier maintenance for the residents. In areas where electricity reliability is a concern, utilizing a brass pot for water heating proves to be a cost-effective and sustainable solution, as opposed to employing high-tech methods like solar energy. Embedding a brass pot outside the house, and heating it from locally sourced pyre wood keeps the smoke outside the house and does not adversely affect the indoor environment, eliminating the need for annexures like chimneys.

Need for Local Labour

As per an architect based in Kerala, "*It is not advisable to look at technology-based solutions for construction, in a country like India which has a large pool of local labour*". The availability of local labour is a key consideration in indigenous construction. Unlike Western countries with limited labour pools, India has a vast workforce primarily sourced from suburban and rural areas. The need to employ both skilled and unskilled labourers was emphasized, along with the call for a behavioural change in existing practices. One respondent said "*The existing practices call for a behavioural change*". Architects and practitioners highlighted the importance of integrating indigenous practices and labourers' skills by modifying plans to align with their familiarity and expertise.

"*In earlier days, architecture had a broader social science and humanities focus.*" A critique of the current educational approach in universities was expressed by an architect pursuing a Master's degree in Human Geography. The architect lamented that the present teaching methods fail to instil a sense of reflection on the human and sustainable aspects of construction among today's generation. While it is expected that construction, being a vast field, may contribute to environmental damage, it is not an unavoidable consequence. Irrespective of the field, people and societal concerns should take precedence. It is crucial for architects and practitioners in the construction industry to comprehend human issues and design and construct accordingly.

According to an architect from the Pune region, rather than introducing unfamiliar concepts to students, it would be more effective to adapt the curriculum to their existing skills. "*Instead of teaching the local workers something non-traditional, modify the plan according to the skills of these workers*". Working with what people already know is always easier. Indigenous construction methods involve employing local labour and utilizing traditional techniques specific to the region. To ensure that labourers operate within their comfort

zone, plans should be modified to incorporate indigenous practices and leverage the skills of the labourers.

Economic Aspects of Construction

The economic aspect of construction was discussed, with one practitioner remarking on the need to address the economic growth versus environmental impact dilemma. "*People talk about indigenous natural buildings in air-conditioned rooms*". The desire for environment friendly houses at lower costs was cited as a common expectation. Eco-friendly buildings may not be cheap upfront, but they prove to be economically beneficial in the long run. "*A conventional flat, in a good locality, costs around Rs. 5000 per sq. ft. However, it is expected to have an environment-friendly house for Rs. 1800 per sq. feet,*" These structures prioritize occupant health and well-being and have lower maintenance requirements, leading to overall cost savings. Additionally, local sourcing of materials reduces transportation costs. "*Eco-friendly buildings are not certainly cheap; but these are economic in the long-run*."

The primary emphasis of eco-friendly buildings is on promoting the health and well-being of their occupants. The maintenance of such structures is greatly influenced by the lifestyle choices of the users. While the construction of these houses may require more time compared to modern houses, they tend to have a significantly longer lifespan. Additionally, the maintenance requirements for these houses are minimal, making them suitable for small-scale construction projects. In essence, eco-friendly structures offer cost advantages in the long run as they involve lower material costs, reduced transportation expenses, and require less maintenance.

Region Specific Choices

Upon analysing indigenous construction methods, materials, local labour, and the economic aspects of indigenous construction, we discovered that all these factors share a common foundation of supporting sustainability, while also exhibiting region-specific variations. Our objective was to explore the integration of vernacular architecture with indigenous practices, which involved conducting an in-depth study of available literature to gather secondary data, as well as conducting interviews with selected practitioners from the specific regions. Below are some key findings from the secondary sources:

i. Kashmir: Known for its breath-taking beauty, Kashmir not only boasts natural splendour but also showcases an architecture that harmonizes with its geography. The influence of Central Asian styles is still evident in the construction practices there (Selina, 2017). Craftsmen utilize locally sourced stone, wood, and brick as the primary building materials. Deodar and walnut, indigenous trees, are used for ceilings and wooden panels, featuring interlocking geometric patterns inspired by Persian art. These stone and wooden houses not only exhibit environmental friendliness but also offer aesthetic appeal. They provide structural stability, capable of withstanding strong seismic activity. The architectural style in this region reflects a blend of colonial and vernacular influences.

ii. Himachal Pradesh: The enduring structures of Himachal Pradesh stand as significant symbols of its ancient heritage. Houses in this region employ wooden beams and double-skinned walls, which help maintain warmth in winter and coolness in summer. The traditional Kath Kuni technique of construction is prevalent in rural Himachal Pradesh. Such structures are built using dry masonry along with alternating layers of wooden beams, without the use of cement. The stone plinths which is above the ground level enhances strength of the structure and also prevent snow and groundwater infiltration. Unfortunately, such eco-friendly architecture, crafted with local resources is gradually fading as increasing number of people are opting for concrete houses.

iii. North and Northeast India: Numerous articles/ journals highlight information on houses built using vernacular architecture in north India that can withstand earthquakes (Ortega *et al.*, 2017). Many regions in North and Northeast India fall under medium/high seismic zones. In these areas, bamboo trees are abundantly found and it holds significant socio-cultural importance for the local communities. Houses

constructed with bamboo exhibit resilience against heavy monsoons and earthquakes, particularly in regions like Meghalaya and Assam. Bamboo houses in the North and Northeast regions are constructed using lightweight/natural materials such as thatch and the plinth level is made up of cement and brick. The structure of the frame is crafted from bamboo & wood, which is then plastered by using mud. Depending on the client preferences, the roof is covered with thatch or galvanized sheets. Thatched roofs are commonly found in low-budget houses. Notably, although the flooring is done using bamboo, and floor levels are raised to successfully withstand the floods.

iv. Eastern parts of India lie in the humid-subtropical zone and experience heavy rainfall, hot summers, and mild winters and include states of West Bengal, Bihar, Odisha, and Jharkhand which showcase architectural features inspired by ancient styles. With abundant rivers and forest cover, these states offer ample natural resources. Mud and wood were traditionally prevalent building materials, but as mining evolved, stone became extensively used. Noteworthy features include lightweight sloping roofs, mud architecture, and passive design strategies that enhance thermal comfort.

v. In the central region, comprising parts of Maharashtra and Madhya Pradesh, architects revealed interesting characteristics of houses based on interviews. Lower levels utilize black stone masonry, while bricks, known for their lightweight and easy handling, are used for greater heights. Instead of cement, mud mortar is used to bond the bricks, with mud sourced directly from the site. Teak, a conventional material, is replaced with fast-growing timber commonly found in Maharashtra to avoid harming the ecosystem. Clay tiles bonded with lime plaster, known for easy maintenance and temperature regulation, are used for roofing.

vi. In the western region, states like Rajasthan, Gujarat, and Punjab experience extreme heat. In house structures, smaller wooden window openings to minimize heat entry during the day, and open shafts to facilitate fresh air circulation in areas overshadowed by nearby buildings, promoting cross-ventilation, were used. Terrace gardening along with water harvesting system on the roof contributes to the cooling effect. Creation of artificial ponds in compounds adds to aesthetics as well as attracts birds.

vii. South India, comprising Tamil Nadu, Kerala, Andhra Pradesh, and Karnataka, showcases two prevalent earth-building techniques: compressed stabilized earth blocks (CSEB) and rammed earth. These techniques utilize soil, sand, and minimal amounts of cement or lime, resulting in significantly lower embodied energy compared to conventional materials. Binding agents such as cactus juice, lime, and marble powder are employed. Indigenous construction practices in Kerala and Tamil Nadu highlight the strong social and cultural values of the region. These houses utilize natural materials and incorporate traditional architectural principles. Roofs have slopes and are covered with clay tiles to efficiently drain rainwater. Wood is a dominant material used for both interior and structural elements. Open spaces or verandas are meticulously designed to facilitate cross-ventilation and entry of fresh air from the surrounding greenery into the houses.

viii. In the twin states of Andhra Pradesh and Telangana, large homes with courtyards, known as Manduvaillu, were built in the 1950s using wooden pillars and red bricks. These houses still utilize locally sourced materials such as Vadapalli tiles, red bricks, and Cuddapah stones.[44]

These findings shed light on the diverse yet interconnected practices of vernacular architecture, which not only preserve cultural heritage but also offer sustainable solutions for various environmental and geographical challenges in different regions.

Based on secondary sources, Table 3 summarizes the region-specific construction practices as follows:

Table 3: Region-specific construction practices

Region	Site Condition	Materials and Methods
Northern	Cold regions	Kath Kuni architecture: wooden and stone houses[25]
	Seismic zones	Hilly areas - bamboo walls[29]
		Stone masonry construction with interlocking irregular stones[45]
Eastern	Forest cover; rivers	Wood & clay; mud mortar; stone masonry[46]
		Bamboo housing, lightweight sloping roofs[47]
	Heavy rainfall	Mud and stone walls[48]
Central	High day temperatures	Cross ventilation, open spaces, vegetation[49]
		Wood, bricks, stone, mud[50]
Western	Hot	Open shafts for fresh air, terrace garden, relatively small window openings are provided to reduce heat, and water harvesting on the roofs[27]
Southern	Hot & humid	Kerala: Light materials, extensive use of wood, well-designed open spaces[51]
		Andhra Pradesh & Telangana: Vadapalli tiles, Red bricks, Cuddapah stones, wooden pillars52
		Tamil Nadu: Rammed earth[53]

The architectural form of indigenous houses varies across different regions, influenced by local climatic conditions. However, there are certain commonly adopted indigenous practices and house forms that aim to improve the comfort of residents. Embracing these practices, along with the usage of locally available materials, contributes to the reduction of carbon footprint. Given the widespread utilization of indigenous construction materials throughout the country, the following section presents a model for sustainable construction.

Discussion: Model for Sustainable Construction through Indigenous Practices

Drawing upon the study's findings, a holistic model for achieving sustainability through indigenous practices is presented. By incorporating indigenous practices that prioritize environmental, social, and economic sustainability, future construction endeavours can effectively integrate these three crucial components. Figure 4 below illustrates the proposed model.

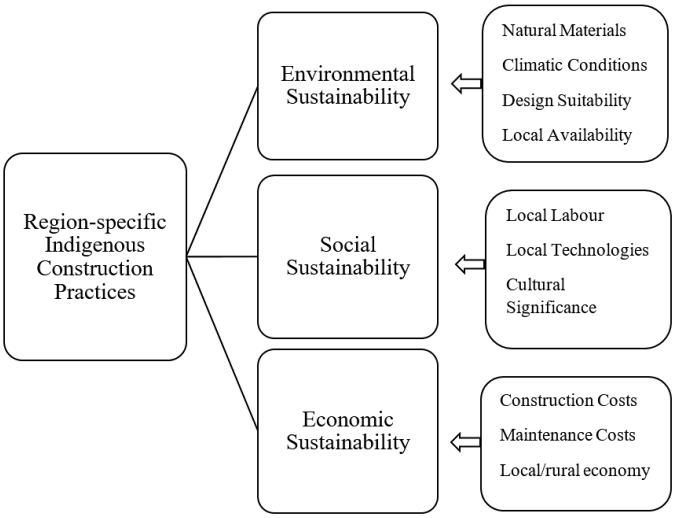

Fig. 4: Model for Sustainable Construction through Indigenous Practices

Environmental Sustainability

"*Indigenous architecture is different yet the same for each location.*" According to an architect, indigenous architecture follows a similar concept of local sourcing, but the materials' properties differ based on geographical location, weather, and climate. Materials like mud undergo simple tests such as jar tests or biscuit tests to assess their suitability, as their properties are specific to the region. Some materials like timber and lime have Indian Standard (IS) codes.

For instance, in Kerala, traditional houses utilize wood and bricks extensively. Rosewood and teak, which are commonly used, can be replaced with fast-growing timber to avoid harming the ecosystem. Alternative types of timber like shiva, ain, and, haiduare prominently used for roof structure and are covered by clay roofing tiles.[54] Construction waste is also considered, with an architect emphasizing the importance of finding ways to utilize waste. "*If I am creating construction waste, I should find ways to dispose it.*" (Architect).

Waste products like fly ash can be considered environmentally friendly when used in producing cement concrete. Brick powder, a waste from brick kilns, can be used instead of river sand. Incorporating indigenous practices and vernacular architecture can help minimize the adverse environmental impact of multi-story buildings. The suggestion is to use region-specific materials and methods that are locally available and suitable for the climatic conditions.

Social Sustainability

Sustainable construction aims for long-lasting buildings that positively impact the environment and promote longevity. Reviving indigenous practices involves employing local labour, which not only preserves the culture but also contributes to social upliftment. According to an architect, learning from the locals and incorporating contemporary elements breathes life into the indigenous practices. "*Learn from the local people and be contemporary.*" (Architect).

Local labourers understand the region's climate, cultural preferences, and the clients' interests as they are from the same community. Their familiarity with the aesthetic values and requirements of the clients enables them to design structures that are safe, durable, and suitable for the region. These houses prioritize the health along with well-being of the occupants, offering ample ventilation and access to natural light. Using their traditional skills and methods, local labourers handle natural materials and contribute to socioeconomic development in the region.[55] By employing local labour, money circulates within the village or the specific region, stimulating the local economy and promoting growth.

Economic Sustainability

India showcases a variety of sustainable houses built using indigenous techniques. The cost of these houses depends on the scope of work and the type of building. Material costs and labour costs are the two major components of construction expenses, typically following the 80:20 rule in conventional buildings.

Transportation costs are significantly reduced by sourcing materials and manpower locally within a radius of 10-25 kilometres in semi-urban and rural areas. The use of natural or recycled materials reduces a significant portion of the material costs. However, material costs vary across regions due to geographical dependencies. In urban areas, materials often come from distant locations, resulting in increased logistics costs.

The overall cost is influenced by the scope of work and client preferences. In the case of large land areas, the potential use of mud as a cost-effective alternative can reduce expenses. Employing local skilled labour may incur additional costs, but the superior end product compensates for this investment. Additionally, hiring unskilled labour creates employment opportunities and contributes to the local economy. "*As a result of usage of indigenous architecture, money circulates within the village or within the specific region*" (Economist, Architect).

Conclusion

Construction industry plays a pivotal role in the economy, but it also contributes to environmental damage in a significant way. To address this issue, sustainable construction practices need to be developed for modern construction activities.

Indigenous construction practices, known for their sustainability, offer an approach of "reviving from the past" for contemporary construction. This study aims to understand indigenous construction practices in various parts of India and explore their application in the contemporary construction industry. The concept of sustainability through indigenous practices has been investigated through the use of constructivist grounded theory.

The findings of the study reveal a vast scope for implementing indigenous construction practices in the contemporary construction industry. Despite being well-known, many of these practices are not commonly applied today. Conversations with practitioners emphasized the role of conventional materials in building sustainable homes. By utilizing locally available materials, the cost of construction materials, which typically constitute a significant portion of expenses, can be greatly reduced. Although the labour and techniques involved in traditional structures may cost more compared to modern structures, the overall cost of traditional structures remains lower.

Indigenous construction practices are gradually being lost over time. The sustainability of these practices and the satisfaction of clients were evident from the conversations with various practitioners. The study develops a comprehensive model for achieving sustainability through indigenous construction practices, focusing on three types of sustainability viz. environmental sustainability, social sustainability and economic sustainability. The amalgamation of social sustainability and economic sustainability with environmental sustainability in a model is a significant contribution of this paper and paves the way for future research in several ways. suggesting further research on regional climatic conditions.

Limitations and Scope for Future Research

This study examines region-specific indigenous construction practices which is both a strength and limitation of the paper. As India is geographically extremely diverse, it was impossible to cover all the regions of the country within the scope of this paper; hence it calls for future region-specific studies on indigenous construction practices. Conducting a climatic study can enhance understanding of local geography and facilitate the application of indigenous construction practices in the modern construction industry. Addition of more case studies from diverse regions of India can enhance clarity on the indigenous construction practices. The model developed in this study may also be tested and modified as per specific regional attributes in future studies. Different regions may also have unique challenges pertaining to sourcing, marketing, and supply chain management of indigenous materials. Similarly there may be unique challenges in different regions for access to skilled labour. Additionally, investigating, and evaluating the carbon footprint (CFP) of indigenous construction materials can provide insights into their utility in modern construction. Implementing indigenous practices in the modern construction industry faces challenges, particularly in terms of small-scale implementation, as access to skilled labour and indigenous materials may be difficult for small players in the marlet. Adding to this, bringing about about behavioural change in clients in adopting these practices by generating more awareness is crucial for further work. The current study utilized CGT with a limited number of respondents, and including more respondents can lead to more generalized results. Furthermore, we recommend the use of the Delphi technique for validating the model developed in this work, in future research. This study paves the way for robust future research on integrating indigenous construction practices with contemporary construction practices.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

This study was conducted using unstructured interview method of various stakeholders. Majority

of the excerpts of interview data have been included in the manuscript.

Ethics Approval Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Authors' Contribution

Dr. Arpita Mathur: Conceptualisation of the paper, Research Methodology, Data Collection and preparation of the manuscript, Dr. Avinash Bagul: Analysis of the data, Dr. Kirti Rajhans: Review of Literature

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